Damping of Oscillations of a Combustion Chamber by Resonators

The present invention relates to a device for damping oscillations of a combustion chamber, whereby at least one resonator is connected to the combustion chamber in a vibration-damping manner.

Devices of this type are known in principle from the prior art. DE 34 32 607 A1 and US 5,353,598 A describe devices for damping oscillations of a combustion chamber, whereby at least one resonator or one damping chamber is connected directly or via passage channels to the combustion chamber of a rocket engine.

However, a disadvantage of the devices according to US 5,353,598 A is that the resonators are directly connected to the combustion chamber of the rocket engine. An overheating of the resonators can therefore occur due to hot combustion gases entering from the combustion chamber area. As a result the resonators lose their resonance effect and accordingly can no longer help to damp oscillations of the combustion chamber.

In DE 34 32 607 A1, damping chambers are arranged in the area of the injection head in a fuel distribution chamber and connected to the combustion chamber via passage channels in a vibration-damping manner. An active cooling of the damping chambers is ensured through the arrangement in the fuel distribution chamber, which is used, e.g., for distributing hydrogen. However, relatively complex constructive measures are required for this. Nevertheless, it cannot be ruled out that hot combustion chamber combustion gases penetrate via the passage channels directly into the damping chambers and lead to the impairment or even destruction of the damping chambers.

The object of the present invention is therefore to provide an improved way of damping oscillations of a combustion chamber with the aid of resonators.

The subject matter of the invention is a device for damping oscillations of a combustion chamber, whereby at least one resonator is connected to the combustion chamber in a vibration-damping manner. According to the invention it is provided that the at least one resonator is connected to a pre-chamber in a

vibration-damping manner and the pre-chamber is connected via at least one passage channel to the combustion chamber in a vibration-damping manner. It is thereby achieved that the resonator(s) that are used to damp the oscillations are no longer in direct contact with the combustion chamber, or with the interior of the combustion chamber. Rather there is only one indirect connection via the intermediate pre-chamber. The resonators can therefore be arranged in areas that are subjected to a lower thermal stress or smaller temperature changes. Nevertheless, the oscillations of the combustion chamber can reach as far as the resonators via the passage channel and the pre-chamber and so the oscillations of the combustion chamber can be effectively damped.

A first further development of the invention provides that the combustion chamber adjoins an injection head with at least one injection element, which injection head is embodied to conduct a fuel flow into the combustion chamber, and the pre-chamber is fluidically arranged before the at least one injection element. A single fuel flow can thereby be provided, which is fed to the combustion chamber. Two or more fuel flows can also be provided, which are fed through the injection elements to the combustion chamber and optionally are already mixed in or immediately after the injection elements. With this alternative, the pre-chamber is arranged in an area through which at least one of the fuel flows passes before flowing through the injection element(s). The injection elements therefore lie between the combustion chamber or the interior of the combustion chamber and the pre-chamber.

However, alternatively thereto, it can also be provided that the combustion chamber adjoins an injection head with at least one injection element, which injection head is embodied to conduct a fuel flow into the combustion chamber, and the pre-chamber is arranged fluidically in the area of the at least one injection element. The pre-chamber therefore lies in an area through which at least one of the fuel flows passes while flowing through the injection element(s). The injection elements and the pre-chamber are therefore arranged fluidically next to one another in front of the combustion chamber or the interior of the combustion chamber.

In both cases at least one of the fuel flows can be used to keep the temperature of the resonators largely constant through an active cooling of the resonators. For this in particular the pre-chamber can be connected fluidically to a fuel flow, before it reaches the interior of the combustion chamber. The fuel flow is thereby not merely guided around a resonator as, e.g., in the case of DE 34 32 607 A1, but it reaches the interior of the resonator so that the resonance volume of the resonator itself can be kept largely constant at the temperature of the fuel flow. Ideally the resonator as well as the pre-chamber is connected to a gaseous fuel flow, since then a particularly good vibration-damping connection between resonator and combustion chamber can be ensured via the fuel flow.

It is preferably provided that the passage channel is embodied as part of an injection element. However, in principle separate passage channels can also be provided which guarantee a vibration-damping connection between the interior of the combustion chamber and the pre-chamber.

The resonators can be embodied, e.g., as a spherical resonator or as a $\lambda/4$ resonator. Resonators of this type are sufficiently known in principle from the prior art.

A special exemplary embodiment of the present invention is described below on the basis of Figs. 1 through 4 using the example of a rocket engine. They show:

Fig. 1: Rocket engine with spherical resonator in front of the injection head

Fig. 2 Rocket engine with $\lambda/4$ resonators in an injection head cover plate

Fig. 3 Rocket engine with double-row $\lambda/4$ resonators in front of the injection head

Fig. 4: Rocket engine with $\lambda/4$ resonators in the injection head.

With the combustion of fuels in rocket engine chambers, the formation of different high-frequency oscillations often occurs during operation. Due to the high thermal and mechanical stress, such oscillations lead to the damage or even the destruction of the rocket engine if they are not damped promptly.

One method for damping such oscillations is the use of acoustic resonators known from the prior art cited at the outset. A distinction is made here between spherical resonators and $\lambda/4$ resonators. Both resonator types comprise small volumes that are directly connected to the chamber in the case of the devices according to the prior art. A dissipation of the oscillation energy occurs in these resonators when the excited frequency of the chamber coincides with the natural frequency of the resonator. Resonators are narrow-band absorbers and for this reason have to be adjusted to the frequency to be damped. Spherical resonators are used for damping in a broader frequency range compared to the $\lambda/4$ resonators, which have to be adjusted to a discrete frequency. In both cases in addition to the dependence on the geometric dimensions, there is also a strong dependence on the sound velocity and thus on the temperature. There is therefore a danger of a shift of the damping frequency through the heating up of the gas in the resonators. Moreover, the precise adjustment particularly of the more effective $\lambda/4$ resonators is more complex, since the temperature conditions in the resonators can be determined only experimentally and so a readjustment is necessary in most cases. Furthermore, systems of this type are associated with additional constructive expenditure due to the combustion chamber cooling problems present anyway in this area. Resonators arranged axially above the combustion chamber, i.e., against the direction of flow, in the area of the injection head form undesirable return flow zones in this area, whereby an additional heat flow forms in the direction of the injection head, which can impact the stability of the injection head.

The present invention provides a resonator arrangement that is independent of the hot combustion gases and thus of the temperature in the combustion chamber. At the same time, a negative impact of the arrangement of the injection elements and the combustion chamber cooling is avoided. The invention is particularly applicable in the case of full-flow engines and other engines with gaseous injection of one of two or more fuel components. With full-flow engines, gaseous combustion gases of a fuel turbine are fed to a fuel flow (full flow) again and guided together with the fuel flow into the combustion chamber. Another

possible application is represented by expander cycle engines in which the drive of the fuel turbine takes place with a gaseous fuel such as hydrogen. Beforehand the fuel is guided in liquid form through cooling channels of the rocket engine and transferred in a gaseous state due to the heat absorption. With both types of engines, gaseous fuel flows are thus present which are guided via injection elements into the interior of a combustion chamber and combusted there.

Figs. 1 through 3 show examples of a full-flow rocket engine. The engine has respectively one combustion chamber 1 that is delimited upstream by an injection plate 2 of an injection head 3. Injection elements 4 are arranged in this injection head 3, which injection elements are used to guide one or more fuel flows into the interior 9 of the combustion chamber 1. The injection head 3 is delimited upstream by a cover plate 6. The injection elements 4 are either embodied in a tubular manner, but they can also be formed by a combination of tubes and one or more coaxial sleeves. The injection elements 4 or the tubes or sleeves are connected to the injection plate 2 and/or the cover plate 6. The full flow of a gaseous fuel and turbine exhaust gases (gas) reach a pre-chamber 7 before the injection head and are then guided through the injection elements 4 into the interior 9 of the combustion chamber 1.

Fig. 4 shows in contrast an expander cycle engine in which a gaseous fuel flow such as hydrogen (gH2) is guided into a pre-chamber 17 and from there reaches the interior 9 of the combustion chamber via annular gaps 8 between a tube 28 and a sleeve of a coaxial injection element 4. Another, e.g., liquid, fuel flow such as liquid oxygen reaches the interior 9 of the combustion chamber 1 via another chamber 27 and the tube 28.

High-frequency oscillations that develop in the combustion chamber 1 during the combustion of the fuel or fuels, are propagated upstream via fuel gas flows that flow through the injection elements 4 up to a pre-chamber 7, 17. A damping of the oscillations of the combustion chamber 1 according to the invention can thus also occur in that resonators 5, 5a, 5b are arranged in the area of the pre-chambers 7, 17 so that they communicate fluidically with the pre-chamber 7, 17.

Fig. 1 shows an arrangement of a spherical resonator 5 in the wall of the pre-chamber 7. The spherical resonator 5 can thereby be embodied as an annular circumferential chamber in the wall of the pre-chamber 7, which chamber is connected to the pre-chamber 7 via an annular passage gap, as shown in Fig. 1.

Fig. 2 shows an alternative embodiment, whereby λ/4 resonators 5 in the form of cylinders open on one side are arranged in the cover plate 6 of the injection head 3. As shown in Fig. 2, several λ/4 resonators 5 can be arranged distributed uniformly. In the case of Fig. 2, the λ/4 resonators 5 are arranged in an annular manner around the central axis of the cover plate 6.

In Fig. 3 an arrangement of λ/4 resonators 5a, 5b is provided in the wall of the pre-chamber 7. The λ/4 resonators 5a, 5b are thereby embodied as bores in the wall of the pre-chamber 7. These λ/4 resonators 5a, 5b can also be arranged uniformly distributed. In the case of Fig. 3, the λ/4 resonators 5a, 5b are arranged in two rings lying one above the other in the wall of the pre-chamber 7.

In the case of Figs. 2 and 3, in principle all the λ/4 resonators 5, 5a, 5b can be embodied identically in order to damp precisely a defined oscillation frequency. However, the λ/4 resonators 5, 5a, 5b can preferably be embodied differently, so that respectively one group of λ/4 resonators 5, 5a, 5b can be adapted to a specific oscillation frequency. In the case of Fig. 3, the lower λ/4 resonators 5a are embodied as shorter bores and thus adapted to higher oscillation frequencies than the upper λ/4 resonators 5b that are embodied as longer bores.

With the use of a resonator arrangement of this type, the adjustment is made to the respective frequency to be damped, i.e., $f_{(chamber)}=f_{(resonator)}$. The determination of the geometric dimensions is to be made taking into account the respective temperature conditions of the gas in the area of the resonators, since this has a direct influence on the sound velocity and thus also on the frequency.

The same applies in principle to the exemplary embodiment according to Fig. 4. Here λ/4 resonators 5 are provided as bores in the wall of the injection head 3 in the area of a pre-chamber 7, which encloses the injection elements 4. Here, too, the λ/4 resonators 5 can therefore be arranged uniformly distributed, e.g., in an

annular manner, in the wall of the injection head 3 and here, too, several groups of $\lambda/4$ resonators 5 can be present with different adjustment to different oscillation frequencies. As already described, gaseous fuel such as gH2 enters the pre-chamber 7 and is guided via annular gaps 8 into the interior 9 of the combustion chamber 1. This flow path of the gaseous fuel represents a vibration-damping connection between the interior 9 of the combustion chamber 1 and the pre-chamber 7, analogous to the statements above on Figs. 1 through 3. These oscillations thus reach up to the $\lambda/4$ resonators 5 in the wall of the pre-chamber 7 and can there be effectively damped by the resonator effect of the $\lambda/4$ resonators 5.

The essential advantage of the invention lies in the largely constant temperature of the gas in the resonators 5, 5a, 5b for the entire duration of the operation of the engine. Furthermore, a simplification of the construction results in the high-temperature area of the combustion chamber 1, since no further arrangements such as resonators have to be provided, apart from the usual cooling, in the area of the wall of the combustion chamber 1 and in the injection plate. Moreover the construction according to the present invention makes it possible to accommodate a much larger number of resonator examples, since the individual exemplary embodiments according to Figs. 1 through 3 can also be combined so that spherical resonators 5 and/or $\lambda/4$ resonators 5a, 5b can be provided in the wall of the pre-chamber 7 and/or $\lambda/4$ resonators 5 in the cover plate 6.